Proximal Femur Allograft-prosthesis with Compression Plates and a Short Stem

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Abstract Proximal femur allograft-prosthesis composites (APCs) performed with compression plates and a short stem theoretically could minimize the resorption or non-union that reportedly occurs with long stems bypassing the diaphyseal osteotomy. To confirm this theoretical consideration, we retrospectively reviewed 34 patients with 38 proximal femoral APCs using a short-cemented femoral stem and compression plates for diaphyseal osteotomy fixation. In 26 patients, the plate fixation extended over at least half the femoral stem and in 12, it did not. We reinserted the abductor mechanism with two techniques: in 10 cases the host trochanter was reattached to the APC, and in 28 the host tendons were sutured to the tendinous insertion of the allograft. The overall survival of the entire series was 72% at 5 years and 69% at 10 years. Eleven of the 38 (29%) APCs were removed: three for infection, one for local recurrence of tumor, and seven for fractures. Trendelenburg gait occurred in four of 21 patients with direct tendon-to-tendon suture of the abductor mechanism and in three of six patients with trochanteric osteotomy. The overall APC survival rate was greater in patients in whom

the allograft was adequately protected with internal fixation than in patients in whom it was not.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Tumor excision with wide surgical margins or bone destruction from a failed hip arthroplasty implant frequently leads to major osseous defects in the proximal femur. Reconstruction options for these patients include endoprosthetic replacement or composite reconstruction using allografts and prostheses [2, 3, 4, 7, 8, 13, 16, 18, 23, 25]. An osteochondral allograft rarely is indicated for reconstructing the proximal femur [14]. APCs have been used to reconstruct defects from wide tumor excisions since the late 1980s [3, 7, 8, 15, 18, 23, 25]. Advantages of proximal femur APC over endoprosthetic replacement include its ability to support mechanical loads and increased potential for reattaching tendons of the hip. Use of the APC also eliminates the need for articular congruence [3, 7, 8, 18, 23, 25]. One additional purported advantage of allografts over synthetic materials is the former may be incorporated progressively by the host [19, 21, 22]. Disadvantages of bone allografts include potential disease transmission and a somewhat unpredictable incidence of infections (range, 4%–11%), fractures (range, 4%–19%), and resorption (range, 7%–29%) [3, 5, 18, 19, 24].

Several methods for proximal femoral APC have been described, and most include using a long stem bypassing the diaphyseal osteotomy [3, 7, 18, 23]. Long stems potentially reduce the risk of femoral allograft fractures, but these kinds of femoral prostheses transfer loads through

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Each author certifies that his institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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the stem directly to the distal femur, leading to the possibility of stress-shielding in normal bone [1, 10] and resorption and nonunion in bone allograft.

We developed an alternative approach with compression plates and primary short stems. Our rationale was to interfere as little as possible at the host–donor osteotomy site. After achieving solid union the composite would permit physiologic loading and minimize the bypassing of load transmission by a long stem. In addition, the distal part of the allograft, free of cement and prosthetic stem, would allow extended contact between the donor and recipient and a more favorable condition for an endosteal callus to develop. This concept is based on a previously reported observation of retrieved allografts showing the importance of endosteal callus formation to obtain natural osteotomy healing [5]. However, the use of an external plate to fix the construct still may interfere with the physiologic load. The rigid fixation obtained with the plate, however, may contribute to rapid osteotomy healing, and with bone remodeling the plate may become less important in load transmission [5].

We therefore raised several questions: (1) what are the midterm survival and long-term survival of a proximal femur APC performed with compression plates and a short stem; (2) what are the complications; (3) what are the functional outcomes (Musculoskeletal Tumor Society score) in patients treated with this reconstruction; and (4) are age, gender, percentage of the femur resected, percentage of the allograft covered with the plate, or the use of chemotherapy risk factors for APC failure?

Materials and Methods

We retrospectively reviewed 37 patients who underwent 41 proximal femur APCs using a short stem and plate fixation between May 1987 and December 2005. This procedure was indicated for treating massive osteoarticular defects of the proximal femur after tumor resection or massive bone loss attributable to infection, trauma, or hip revision. The primary diagnoses were Ewing's sarcoma in eight patients, osteosarcoma in six, chondrosarcoma in five, metastasis in two, hemangioendothelioma in two, fibrosarcoma in one, hydatidosis in one, and giant cell tumor in one; the remaining 12 patients underwent revisions for failures of endoprosthetic reconstructions performed at other centers. The mean age of the patients was 45 years with a range between 13 and 79 years. We performed 26 of the reconstructions in females and 12 in males. The minimum followup was 3 years (mean, 7.5 years; range, 3–17 years). Three patients were lost to followup during the first 2 years after surgery. This left 34 patients with 38 proximal femur APCs for review (Table 1).

We harvested nonirradiated proximal femur allografts under sterile conditions and stored them frozen at -80°C in the bone bank at our institution according to a previously described technique [20]. The allograft was selected from the bone bank according to the diameter of the femoral shaft and based on comparing radiographs and CT scans of the patient with those of the donor to achieve the closest anatomic match. After it had been thawed in a warm solution, we cut the donor bone to the proper length. The mean allograft length was 16.6 cm long (range, 14–24 cm).

In 28 APCs, we used a posterolateral approach. In these patients the tendons of the abductor mechanism were sutured to the corresponding tendons of the allograft (tendon-on-tendon). A transtrochanteric approach was used in the remaining 10 patients. In these patients the abductor muscles were reattached to the graft through a wire or screws (Fig. 1).

We cemented a short stem with a third-generation technique in the allograft in all cases without bypassing the diaphyseal osteotomy. A cemented acetabular component was used in nine cases, and an uncemented acetabular component was used in the remaining 29 cases. We reduced the composite implant and fixed it with the host femur through a transverse osteotomy with compression plates. No supplementary grafts were used. Of the 38 cases, 12 had a short plate that covered less than half the femoral stem. The other 26 had a long plate that expanded at least half the length of the femoral stem (Fig. 2).

We administered 1 g cefazolin intravenously for the first postoperative day unless there was a history of penicillin or cephalosporin allergy, in which case the patient received 600 mg of clindamycin; no routine anticoagulation therapy was used.

After two days of bed rest, the drains were removed and the wound inspected. We used no postoperative immobilization or braces. Postoperatively, a physical therapist instructed the patients on walking with crutches and muscle contractions. The goal during the first postoperative week was to minimize swelling. The patient was allowed partial weightbearing at 8 to 12 weeks. Patients maintained protected weightbearing until we observed radiographic evidence of bone bridging at the host-allograft junction.

We followed the patients postoperatively at 1 week, 2 weeks, 1 month, 2 months, and 3 months; every 3 months thereafter until 2 years; and then annually. Plain radiographs were obtained at every visit beginning 1 month after surgery.

Two of us (GLF, LAAT) performed functional evaluation of the patients using the revised 30-point functional classification system established by the Musculoskeletal Tumor Society [6]. This functional score measures six parameters: pain, function, emotional acceptance, use of walking supports, walking ability, and gait. Each parameter

Table 1. Patient characteristics

Patient number	Age (years)	Gender	Diagnosis	Plate	CH	AP	TNU	TB	Femur resected (cm)	MSTS	Complication	Follow-up	Revision surgery
1	59	F	CS	Short	No	PL	No	NA	19	NA	FX	18	APC
2	63	F	CS	Short	No	PL	No	NA	17	NA	FX	25	APC
3	51	F	HEM	Short	No	PL	No	NA	17	NA	FX	26	APC
4	18	M	Ewing	Short	Yes	PL	No	NA	15	NA	FX	24	APC
5	19	M	OS	Long	Yes	PL	No	NA	16	NA	FX	46	ENDO
6	18	M	Ewing	Short	Yes	PL	No	NA	17	NA	FX	50	APC
7	20	M	CS	Short	No	TT	Yes	NA	20	NA	FX	62	ENDO
8	49	M	REV	Long	No	PL	No	NA	17	NA	INF	17	Spacer
9	13	M	Ewing	Short	Yes	TT	Yes	NA	18	NA	INF	23	ENDO
10	47	M	CS	Short	No	TT	Yes	NA	18	NA	LR	30	AMP
11	20	F	Ewing	Short	Yes	TT	No	NA	16	NA	INF	18	ENDO
12	70	F	TCG	Short	No	PL	No	No	14	23	No	176	No
13	46	M	REV	Long	No	PL	No	No	15	29	No	190	No
14	66	F	REV	Long	No	PL	No	No	14	28	No	178	No
15	60	F	REV	Short	No	TT	No	No	17	30	DU	201	Autograft
16	60	F	FS	Long	No	TT	Yes	Yes	15	26	No	186	No
17	65	F	REV	Long	No	PL	No	No	17	30	No	183	No
18	40	F	Hydatidosis	Long	No	PL	No	No	16	29	No	89	No
19	76	F	REV	Long	No	TT	Yes	No	15	22	No	170	No
20	21	F	Ewing	Long	Yes	PL	No	No	16	30	No	159	No
21	13	F	Ewing	Long	Yes	PL	No	No	15	29	No	34	No
22	16	F	OS	Long	Yes	PL	No	No	14	30	No	25	No
23	58	F	OS	Long	Yes	PL	No	No	16	28	DU	120	Autograft
24	39	F	Ewing	Long	Yes	PL	No	Yes	17	26	No	56	No
25	21	M	REV	Long	No	PL	No	No	18	27	No	98	No
26	79	F	REV	Long	No	PL	No	Yes	21	13	No	27	No
27	55	F	REV	Long	No	PL	No	Yes	19	26	No	70	No
28	15	F	Ewing	Long	Yes	PL	No	No	16	29	No	200	No
29	64	F	REV	Long	No	PL	No	No	17	28	No	74	No
30	66	F	OS	Long	Yes	PL	No	No	18	30	No	90	No
31	60	F	HEM	Long	Yes	PL	No	No	23	30	No	74	No
32	25	F	OS	Long	Yes	PL	No	Yes	14	26	LR	67	Resection
33	60	F	CS	Long	No	TT	Yes	Yes	15	26	DU	178	Autograft
34	60	F	REV	Long	No	TT	Yes	No	16	30	No	160	No
35	60	F	REV	Long	No	TT	Yes	Yes	15	22	No	112	No
36	67	M	MTS	Long	No	PL	No	No	17	29	No	105	No
37	16	M	OS	Long	Yes	PL	No	No	15	27	No	34	No
38	56	M	MTS	Short	No	PL	No	No	17	28	No	45	No

CS = chondrosarcoma; Hem = hemangioendothelioma; OS = osteosarcoma; REV = revision of another reconstruction; FS = fibrosarcoma; MTS = metastasis; GCT = giant cell tumor; CH = chemotherapy; AP = approach; TT = greater trochanter osteosynthesis; PL = tendon-to-tendon reconstruction; TNU = trochanteric nonunion; TB = Trendelenburg gait; FX = fracture; INF = infection; LR = local recurrence; DU = delayed union; APC = allograft-prosthesis composite; ENDO = endoprostheses; AMP = amputation; NA = not available.

is given a value ranging from 0 to 5 according to specific criteria. The individual scores are added together to obtain an overall functional score with a possible maximum of 30 points.

We considered the procedure failed when the reconstruction was removed either during a revision procedure or amputation. Descriptive statistics were calculated using means and proportions as appropriate to the type of data.

Fig. 1A–B (A) In 10 patients, a transtrochanteric approach was used and the abductor mechanism was reattached to the allograft with wires or screws. (B) In the remaining 28 patients, a posterolateral approach was used and tendons of the abductor mechanism were sutured to the corresponding tendons of the graft.

Fig. 2A–B (A) In 12 patients, a short plate was used without allograft protection at the tip of the femoral stem. (B) In the remaining 26 patients, the internal fixation superposed at least half of the femoral stem to avoid unprotected allograft areas.

We calculated survival of the APC using the Kaplan-Meier method using failure as an end point [17]. We then determined whether age, gender, percentage of the femur

Table 2. Analysis of risk factors

Variable	Number of cases	Failures	p Value
Age			
> 40 years old	15	6	0.48
< 40 years old	23	5	
Gender			
Male	12	7	0.04
Female	26	4	
Percentage of femur resected			
< 18 cm	29	7	0.39
> 18 cm	9	4	
Type of plate			
Long	26	3	0.02
Short	12	8	
Use of chemotherapy			
Yes	15	5	0.39
No	23	6	

resected, percentage of the allograft covered with the plate, or the use of chemotherapy predicted survival of the APC using univariate and multivariate (Cox) analyses (Table 2). We used SPSS 17.0 for Windows (Chicago, IL) for statistical analyses.

Results

The overall survival rate of the entire series was 72% at 5 years (standard error [SE], 7.5%) and 69% at 10 years (SE, 7.8%). The mean prosthetic duration was 149 months (SE, 13.2; 95% confidence interval, 122.9–174.6) (Fig. 3).

Eleven APCs failed as a result of seven fractures, three infections, and one local recurrence (Table 2). In the group of patients with an internal fixation (plate) that covered less than half the femoral stem (12 cases), six allograft fractures were observed. One fracture was observed in the group of patients (26 cases) with internal fixation that spanned at least half the femoral stem. In these seven patients with fractures, removal of the allograft was necessary. A second allograft-prosthesis was performed in five cases, and the remaining two patients had revision with a metal prosthesis. Infection occurred in three patients; these patients underwent a second limb-salvage procedure after removal of the allograft and achieving infection control. They had reconstruction with different procedures (endoprostheses in two and a permanent cement spacer in one). Although two patients had local tumor recurrence, only one underwent amputation and this patient's outcome was considered unsuccessful. In the other patient, the limb was salvaged with the soft tissue local recurrence resection with no

compromise of the reconstruction. No patients had a dislocation and none had failed prosthetic components during the followup period. Three patients underwent a second surgery at an average of 12 months (range, 11–13 months) for delayed union at the diaphyseal osteotomy; autologous bone graft was added in all three patients and all achieved healing after this surgery. None of these patients underwent implant removal.

At the time of last followup, 27 of the original allografts were still in place and available for functional evaluation, with an average functional score of 27 points (range, 13–30 points). Among the 21 patients with a posterolateral approach direct tendon-to-tendon suture of the abductor mechanism, 17 had no Trendelenburg gait and four did. Of the six patients treated with a transtrochanteric approach, five of the six had a trochanteric nonunion and three had a

Fig. 3 A Kaplan-Meier curve shows survival of the allograft-prosthesis composite (APC).

Fig. 4 A Kaplan-Meier curve shows the allograft-prosthetic composite (APC) survival according to the osteosynthesis used. Patients who had a short plate had worse ($p = 0.02$) APC survival.

Trendelenburg gait. The percentage of patients with a Trendelenburg gait was similar in both groups.

The overall APC survival rate was greater ($p = 0.02$) in patients in whom the allograft was adequately protected with internal fixation compared with those in whom it was not (Fig. 4). We observed no relationship between the overall allograft survival rate and age ($p = 0.48$), the percentage of the femur resected ($p = 0.39$), or the use of chemotherapy ($p = 0.39$). However, females had greater ($p = 0.04$) overall APC survival than males (Table 2).

Discussion

The primary objective of tumor surgery is local tumor control, and after adequate resection the surgeon must decide which reconstructive procedure is best suited for the patient. APC reconstruction restores bone stock and provides a biologic anchor for attachment of the abductor tendon but is vulnerable to complications associated with large segmental allografts. We report a group of patients treated with APC performed with compression plates and primary short stem. The rationale of the proposed fixation of APC is to interfere as little as possible at the host–donor osteotomy site. We analyzed survival of these reconstructions, the complications, and functional outcomes of the surviving grafts.

Our study has certain limitations. We retrospectively collected all data and there was no control group with alternate approaches. The group had some inherent heterogeneity in terms of chemotherapy and diagnosis which could have affected the incidence of complications.

In this series of 38 cases, the 5- and 10-year survival rates of the entire series were 72% and 69%, respectively. These rates are similar to those of other reconstruction techniques (Table 3).

The most common complication and cause of failures in this series was femoral fracture (seven of 38 cases) (Table 2). Most of these occurred in the group of patients with short internal fixation (six of the seven cases). This

complication occurred more frequently than with other series with APC that used long stems [3, 7, 18, 23, 25]. We now attempt to minimize this complication using a long plate. We believe stresses at the tip of the prosthetic stem should be neutralized when the entire APC is protected with the plate.

The rate of infection in our series was 8%. Others have reported rates from 0% to 20% [3, 15, 18, 23, 25]. Possible explanations include allograft contamination during the manipulation and longer operating time. To minimize this complication, some precautions were taken: since 1996, all such surgeries have been performed in operating rooms with vertical laminar airflow systems using intravenous prophylactic antibiotic therapy and antibiotic-loaded cement.

Union of the allograft to the host bone must be obtained to avoid excessive long-term stress on the plate and non-union [21]. To minimize these complications, we cemented a short stem into the graft, leaving free allograft bone to contact at the level of the osteotomy. After cementation, we made a congruent plane osteotomy and reduced the allograft with the host bone using compression plates. With this type of reconstruction, we minimized damage to the patients' endosteum, ensuring the entire compression passes through the osteotomy site.

At the time of last followup, 27 of the original allografts were still in place and available for functional evaluation, with an average functional score of 27 points (range, 13–30 points). Compared with endoprosthetic replacement, the advantages of APC reconstruction relate primarily to improving hip abductor strength and gait [3, 7, 8, 18, 25]. This translates to a modest improvement in the overall MSTS functional score but this small improvement may be important to a young patient. Reattaching the abductor muscles is a matter of debate [3, 7–12, 20]. Among the 21 patients in whom the tendons of the abductor mechanism were sutured to the corresponding tendons of the allograft (tendon-on-tendon), only four had a Trendelenburg gait. In the other six patients treated with a transtrochanteric approach, three had a Trendelenburg gait.

Table 3. Results comparison of APCs from the literature

Study	Number of cases	Followup (years)	Allograft fractures (%)	Infections (%)	Diaphyseal nonunion (%)	Loosening (%)	Dislocation (%)	APC success (%)
Langlais et al. [18]	21	6	0	0	28.6	14.3	0	81%
Donati et al. [3]	27	5	66.6	3.7	3.7	0	0	93%
Farid et al. [7]	20	6	4	5	10	0	10	86%
Zehr et al. [25]	18	9.5	0	16.6	5.5	0	0	76%
Safir et al. [23]	50	16	0	4	6	12	8	84%
Current study	38	7.5	18.4	7.4	7.4	0	0	72%

We found the most common complication of these reconstructions was fracture, but this risk was less in patients with longer plates covering at least half the femoral stem. We believe a short prosthesis should be cemented in the graft leaving free distal bone to allow compression through the osteotomy site, decreasing the risk of nonunion. Patients in whom the host greater trochanter was reattached to the APC had a Trendelenburg gait develop more often than in patients with a tendon-to-tendon repair. Our data suggest this type of reconstruction requires the use of appropriate long plates and soft tissue suturing of the abductor muscles between the donor and recipient to increase survival and clinical function of these APCs.

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